Systematic analysis of the resolution of inversions of airborne gravity data for bathymetry beneath floating ice

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The size and geometry of the water cavity beneath floating ice provides important constraints on ice-water interactions and therefore on possible ice shelf thinning and grounding line retreat. NASA's Operation IceBridge has carried out airborne surveys over a large number of glaciers and ice shelves in both Antarctica and Greenland. Collection of gravity data on these flights along with coincident lidar and radar data allows inversion of the gravity data to determine the bathymetry beneath floating ice and the bed in areas where radar cannot image it. Gravity inversions for bathymetry have been published for Thwaites Glacier (Tinto and Bell, 2011) and the Larsen C Ice Shelf (Cochran and Bell, 2012). Since the bathymetry in these areas is not directly observable, it is difficult to evaluate how well these inversions match the actual bathymetry. The few places where the inversions can be compared with measured bathymetry suggest a resolution of about 50 m. In order to assess the resolution and accuracy of gravity inversions, we simulated an inversion for bathymetry beneath an ice shelf by inverting gravity anomalies obtained from forward modeling of a detailed bathymetric survey just seaward of the Dotson Ice Shelf in West Antarctica

The gravity anomalies were sampled along simulated flight lines with a spacing characteristic of an OIB survey (5 km) and filtered with the filter (9.8 km spatial filter equivalent to a 70 second temporal filter) used for OIB data. The resulting simulated gravity profiles were inverted using two different approaches that have been used with OIB data.

1) The gravity anomalies were gridded and the gridded anomalies were inverted using the Parker-Oldenburg technique. This technique assumes that the anomalies arise from variations on a single interface (water/rock) and is appropriate where the ice is floating.2) The bathymetry along the individual profiles was determined by iterative forward modeling of the individual gravity lines. The resulting bathymetric profiles were then gridded to obtain the bathymetric grid. This technique is appropriate where ice is grounded in part of the survey area and also allows variations in bed density and the presence of sediments to be modeled.

In our experiment, the two methods give similar results. For relatively closely spaced lines (5 km) the inverted bathymetry is within about 25 m - 35 m of the actual bathymetry when it is filtered with the same 9.8 km filtered that is applied to the gravity measurements. In other words, the small-scale, short-wavelength relief is not recovered, but bathymetry is well reproduced at wavelengths greater than about 10-15 km. As the line spacing increases to 10 km or more, the shape of the bathymetry is reproduced, but the inferred depths deviate more from the actual filtered depths. The deviation is greater midway between the gravity lines. This is due to the gridding process and the need to fit a surface over more broadly spaced lines.